CERES Angular Distribution Model Working Group Report

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Delivered Edition 4 ADMs and the ADM methodology paper is published!

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Next-generation angular distribution models for top-of-atmosphere radiative flux calculation from CERES instruments: methodology

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Abstract. The top-of-atmosphere (TOA) radiative fluxes are critical components to advancing our understanding of the Earth's radiative energy balance, radiative effects of clouds and aerosols, and climate feedback. The Clouds and the Earth's Radiant Energy System (CERES) instruments provide broadband shortwave and longwave radiance measurements. These radiances are converted to fluxes by using scene-type-dependent angular distribution models (ADMs). This paper describes the next-generation ADMs that are de-

and window (WN) ADMs are developed by combining surface and cloud-top temperature, surface and cloud emissivity, cloud fraction, and precipitable water. Compared to the existing ADMs, the new ADMs change the monthly mean instantaneous fluxes by up to 5 $\mathrm{W\,m^{-2}}$ on a regional scale of 1° latitude × 1° longitude, but the flux changes are less than 0.5 $\mathrm{W\,m^{-2}}$ on a global scale.

Uncertainties of the monthly regional mean TOA fluxes: direct integration

		Terra 2002		Aqua 2004	
		Bias (Wm^{-2})	RMS (Wm^{-2})	Bias (Wm^{-2})	RMS (Wm^{-2})
SW	January	0.04	0.97	0.11	1.00
	April	0.08	0.79	-0.16	0.75
	July	-0.20	1.08	0.11	0.90
	October	0.02	0.65	0.15	0.78
LW	January	0.37	0.72	0.29	0.64
	April	0.47	0.76	0.37	0.60
	July	0.44	0.78	0.31	0.71
	October	0.39	0.65	0.36	0.61
WN	January	0.19	0.30	0.18	0.29
	April	0.24	0.34	0.21	0.29
	July	0.23	0.35	0.19	0.31
	October	0.20	0.29	0.22	0.30

Uncertainties of the instantaneous TOA fluxes

- Uncertainties are derived from consistency tests
- Relative consistency is converted to TOA flux error using theoretical relationship

	Ocean (Wm^{-2})		Land (Wm^{-2})		Snow/Ice (Wm^{-2})	
	Clear	All	Clear	All	Clear	All
SW	1.9	9.0	4.5	8.4	6.0	9.9
LW day	1.5	3.5	2.4	2.9	1.3	2.1
LW night	1.4	2.0	1.2	1.9	1.4	1.4

ADM validation paper and sastrugi paper are submitted!

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Atmospheric Measurement Techniques Discussions
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This discussion paper is/has been under review for the journal Atmospheric Measurement Techniques (AMT). Please refer to the corresponding final paper in AMT if available.

Next-generation angular distribution models for top-of-atmosphere radiative flux calculation from the CERES instruments: validation

W. Su[1], J. Corbett[2], Z. Eitzen[2], and L. Liang[2]

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Atmospheric Measurement Techniques Discussions
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Accounting for the effects of Sastrugi in the CERES Clear-Sky Antarctic shortwave ADMs

J. Corbett[1] and W. Su[2]

Discussion Paper | Discussion Paper |

From Aqua to S-NPP

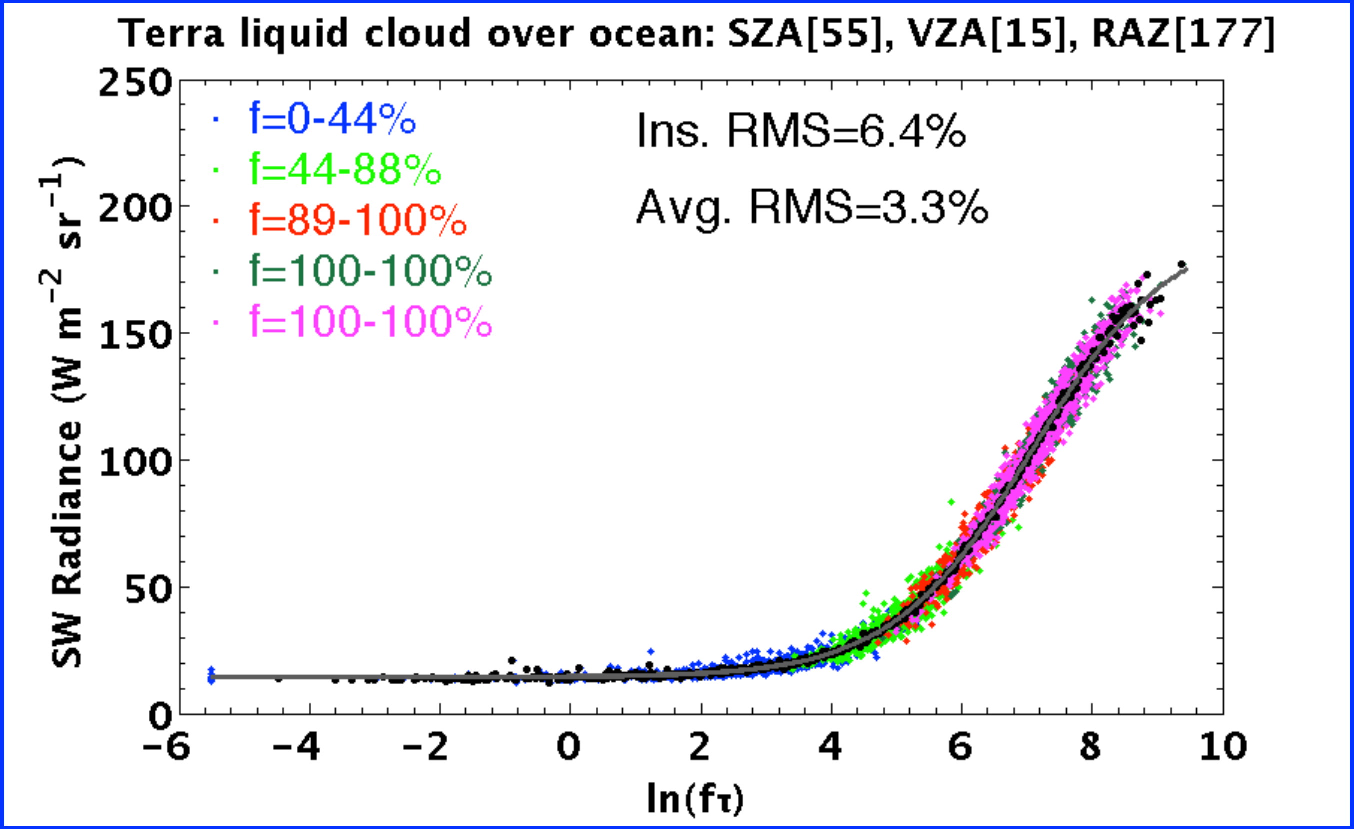
- Footprint size for S-NPP is larger than that for Aqua.
- Cloud properties retrieved from VIIRS can also be different from those retrieved from MODIS.
- How do these differences affect the S-NPP fluxes inverted using Aqua ADMs ?

	Aqua	S-NPP
Launch date	May 4, 2002	Oct. 28, 2011
Altitude	705 km	824 km
Inclination	98.14°	98.75°
Period	98.4 min	101.4 min

Angular distribution model over cloudy ocean

- For glint angle > 20°:
  - Average instantaneous radiances into 775 intervals of ln(fτ);
  - Apply a five-parameter sigmoidal fit to mean radiance and ln(fτ);

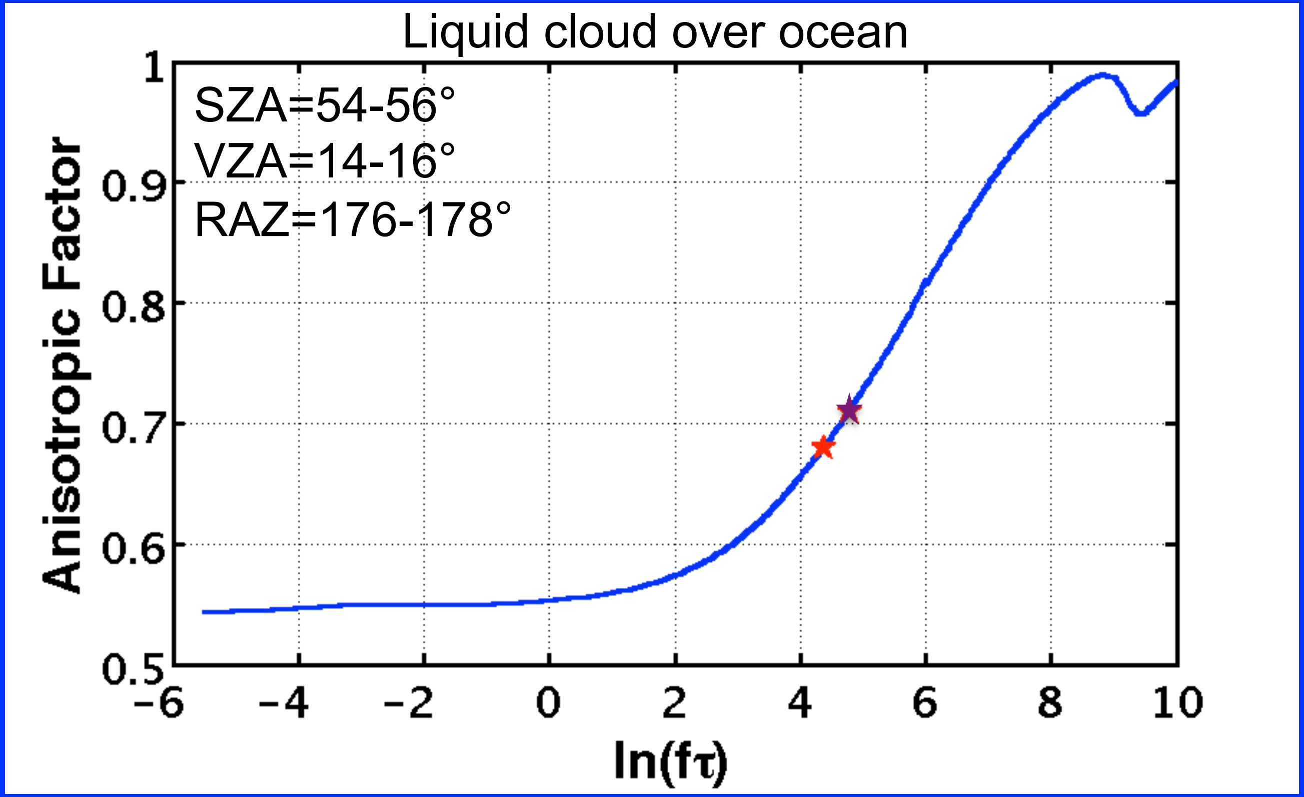
$$I = I_0 + \frac{a}{[1 + e^{-(x-x_0)/b}]^c}$$



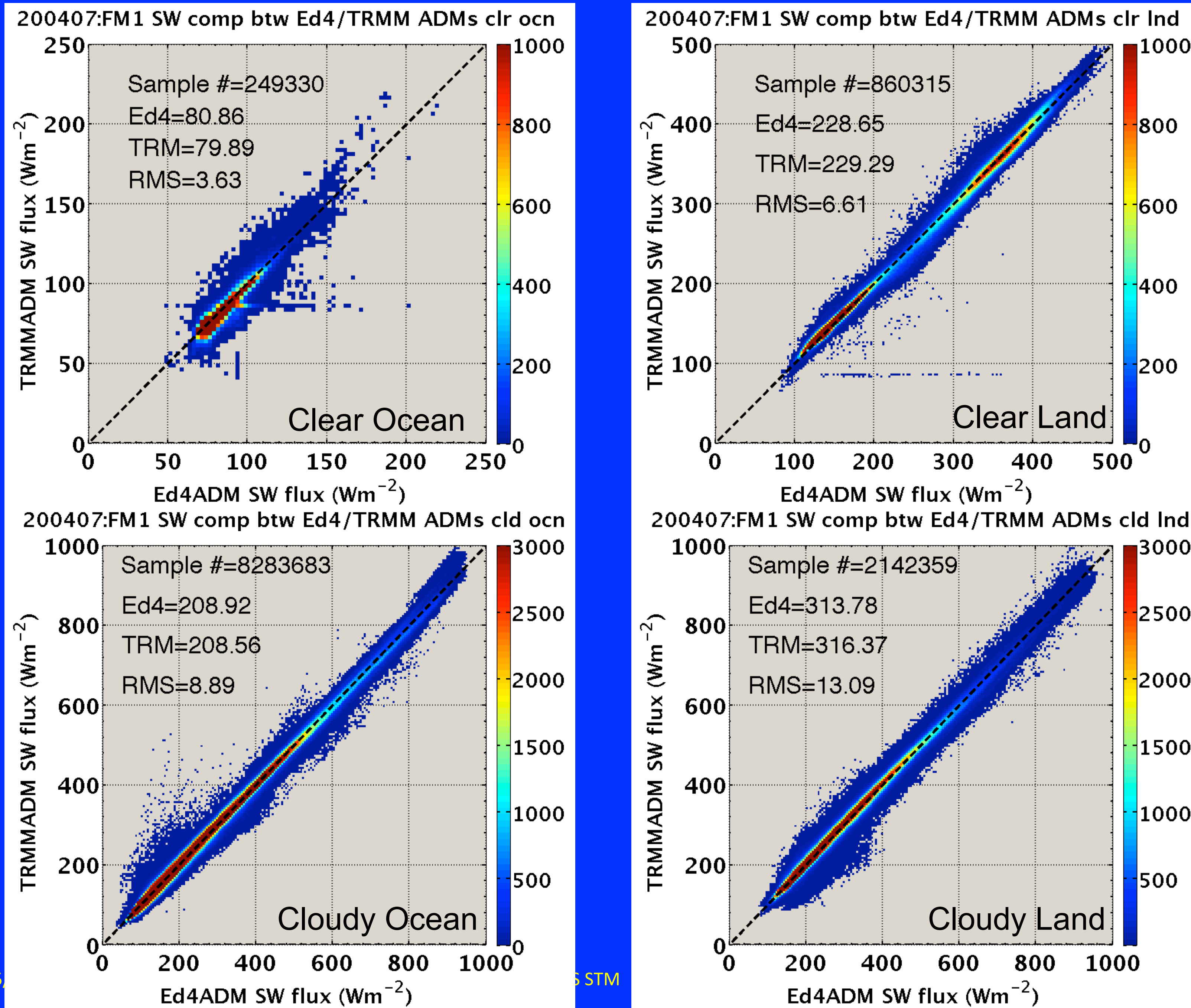
f: cloud fraction
τ: cloud optical depth

Anisotropic factors are sensitive to cloud properties

- For a footprint with cloud fraction (f) of 20% and cloud optical depth (τ) of 4:
  - $\ln(f\tau)=4.38 \longrightarrow$ anisotropic factor=0.68
- If cloud fraction increase by 10%
  - $\ln(f\tau)=4.78 \longrightarrow$ anisotropic factor=0.71
- This results in ~4.4% difference in inverted fluxes

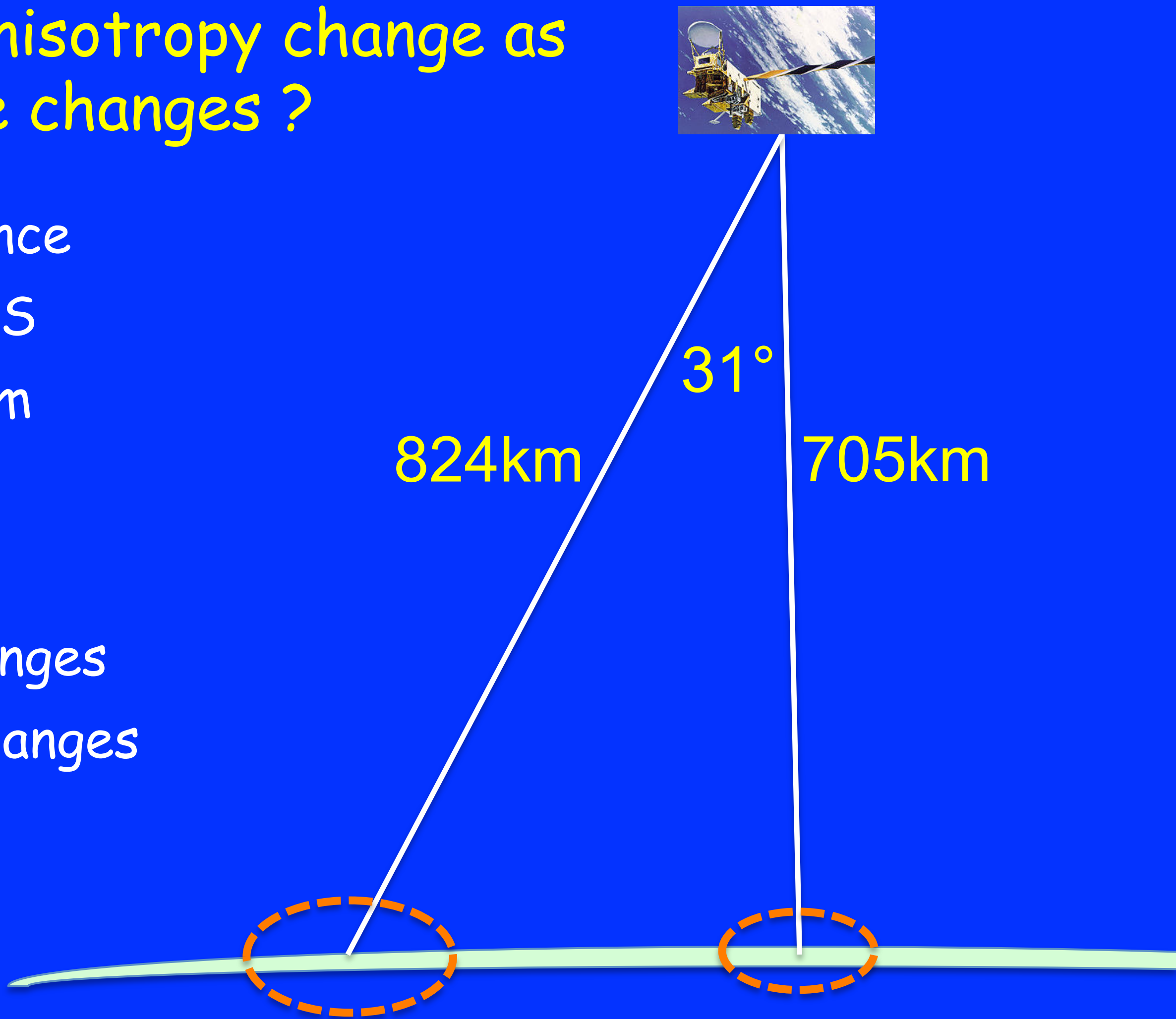


Comparison between tropical flux inverted from TRMM ADMs and Ed4ADMs



Does MISR radiance anisotropy change as footprint size changes ?

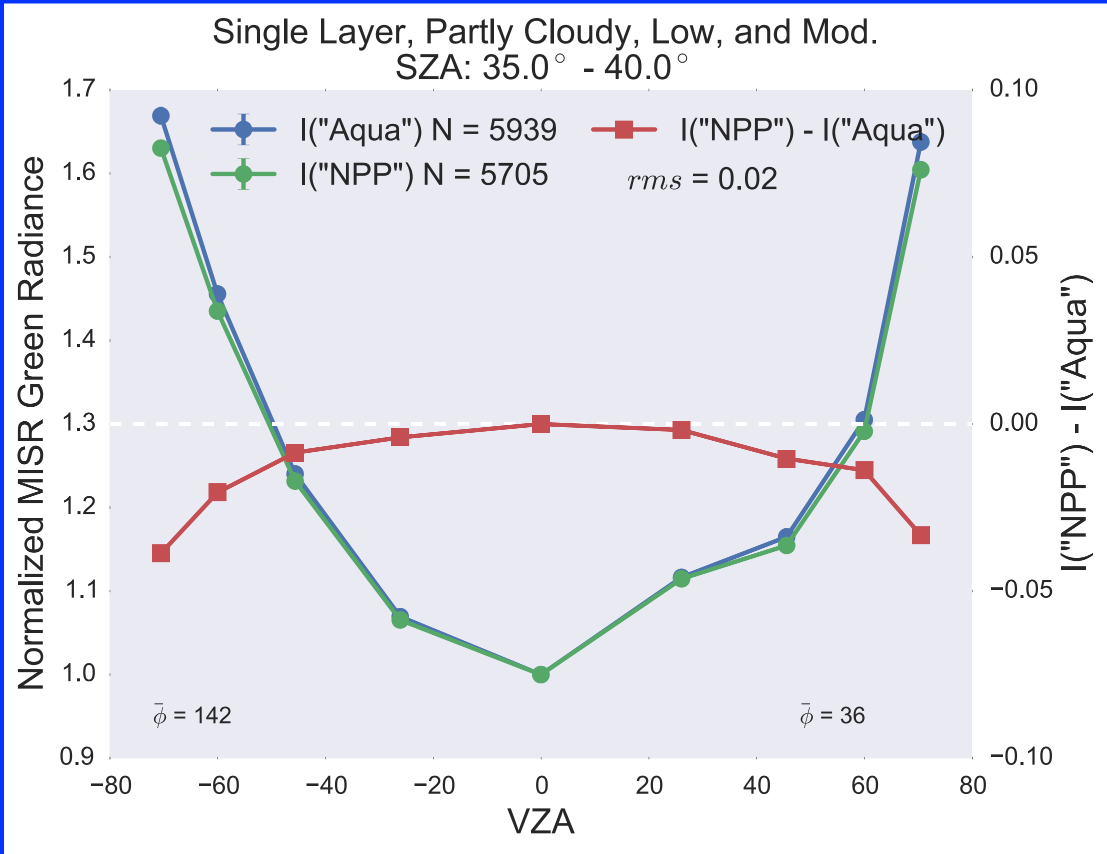
- SSFM data provide radiance anisotropy for each CERES along-track footprint from nine spatially matched directions
- CERES footprint size changes as viewing zenith angle changes
  - At nadir: 16 by 32 km
  - At θ=31°: 18.5 by 37 km
- Examine MISR 0.56 μm radiance anisotropy from these two different size of footprints: I_a and I_n



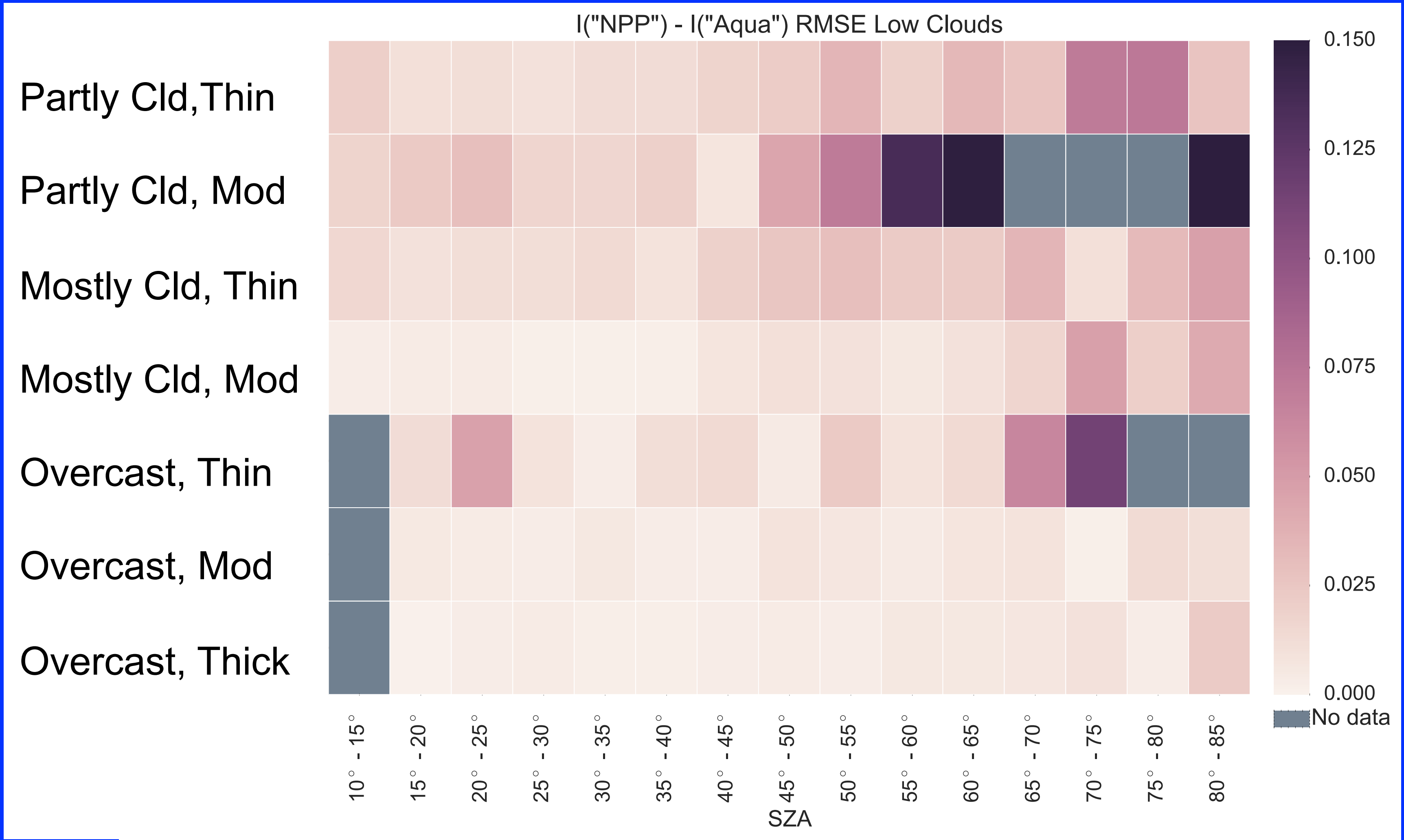
Radiance anisotropy from MISR for different footprint sizes

- Separate the CERES footprints by cloud type and solar zenith angle
- Calculate the mean radiance for each camera angle from the two different sizes of footprints
- Compare the shape of the normalized radiances: $\hat{I}_a$ and $\hat{I}_n$
- Quantify the variation of radiance anisotropy by calculating the RMS error of the normalized radiances: $\sqrt{\frac{\sum_{j=1}^{9}(\hat{I}_{a,j} - \hat{I}_{n,j})^2}{9}}$

PCL: CF =0.1-40%	High: EP<440 hPa	Thin: τ < 3.35
MCL: CF=40-99%	Mid: EP=440-680 hPa	Mod: τ = 3.35 -22.63
OVC: CF=99-100%	Low: EP > 680 hPa	Thick: τ > 22.63



RMS error for different low clouds and solar zenith angle



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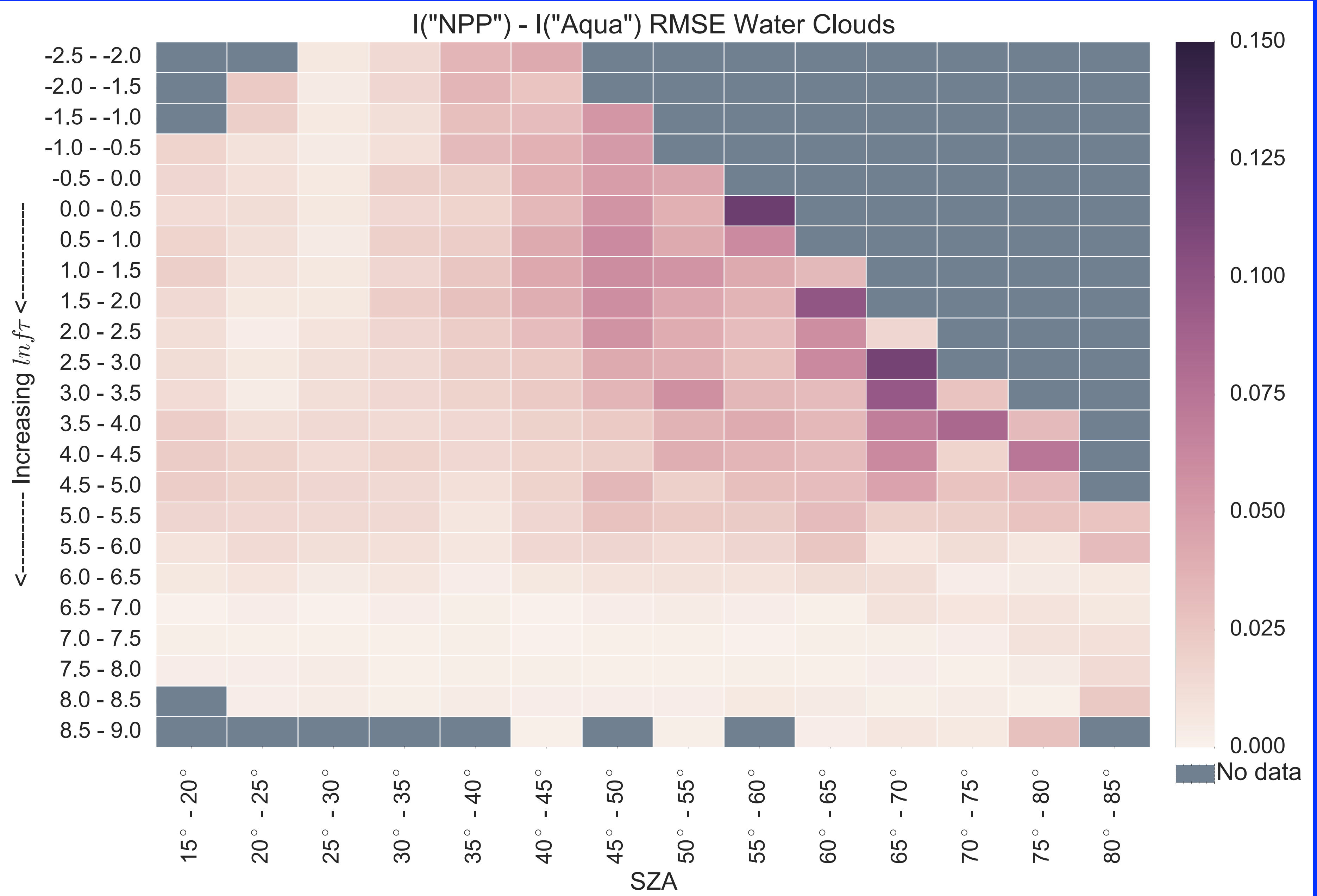
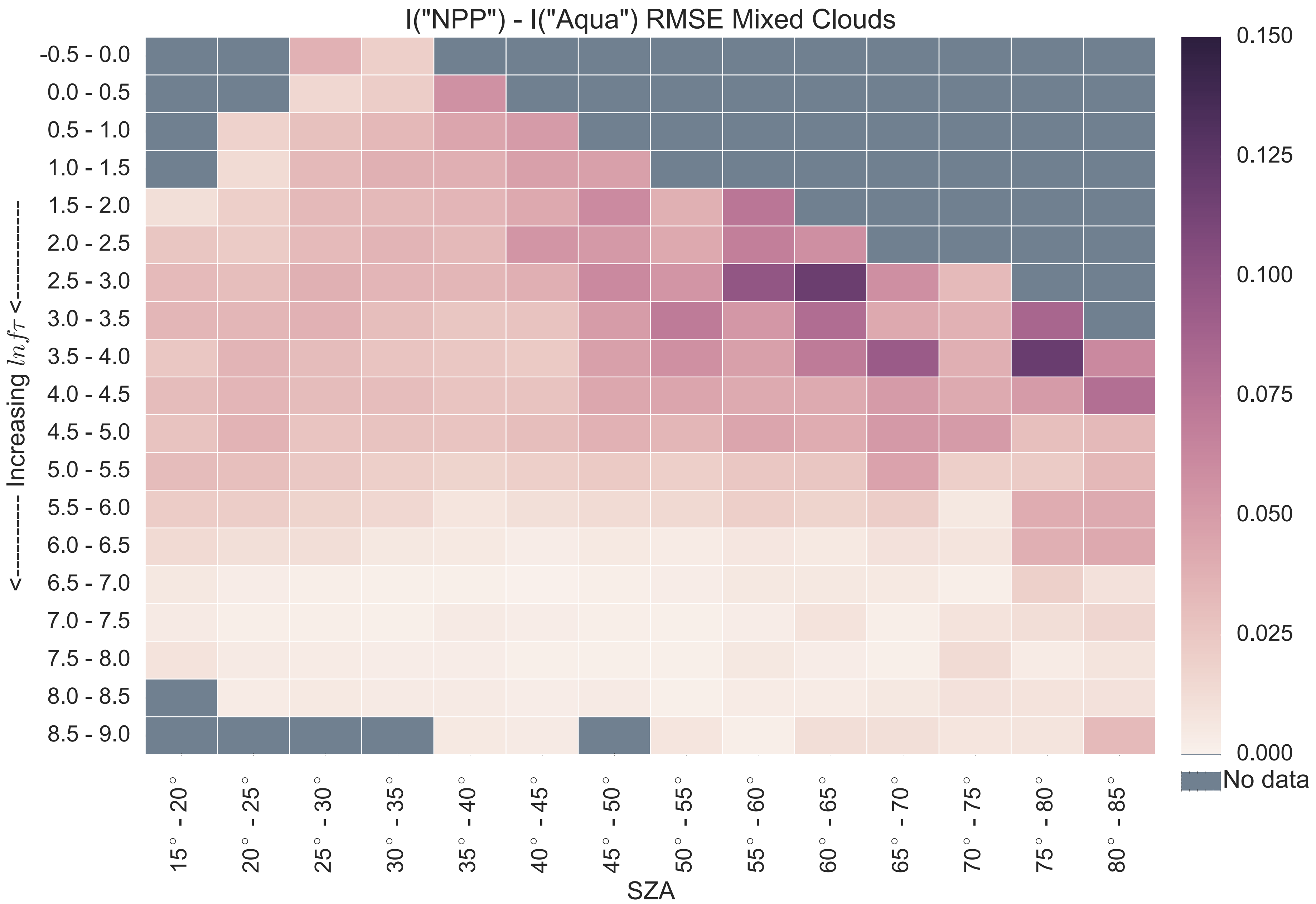
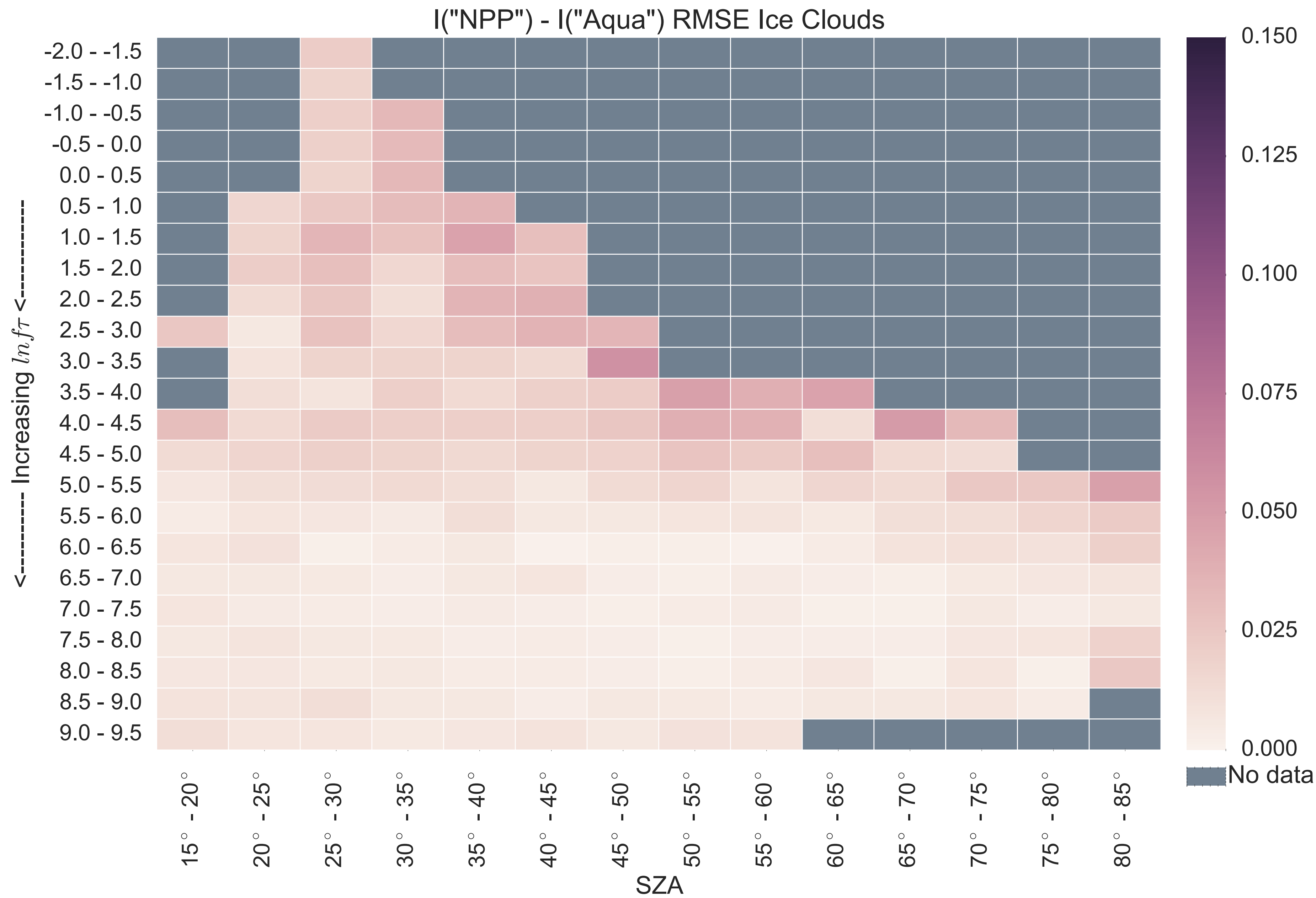
RMS error decreases as ln(fτ) increases: liquid clouds

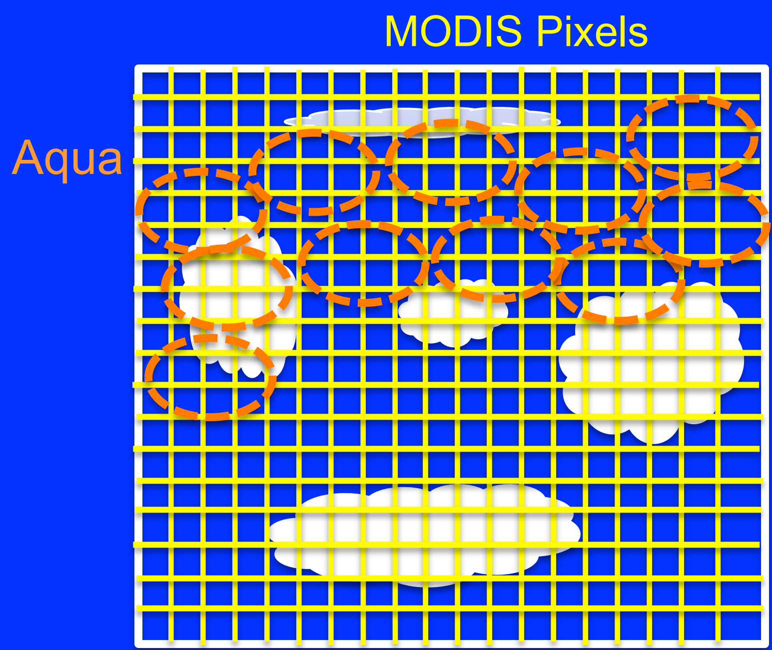


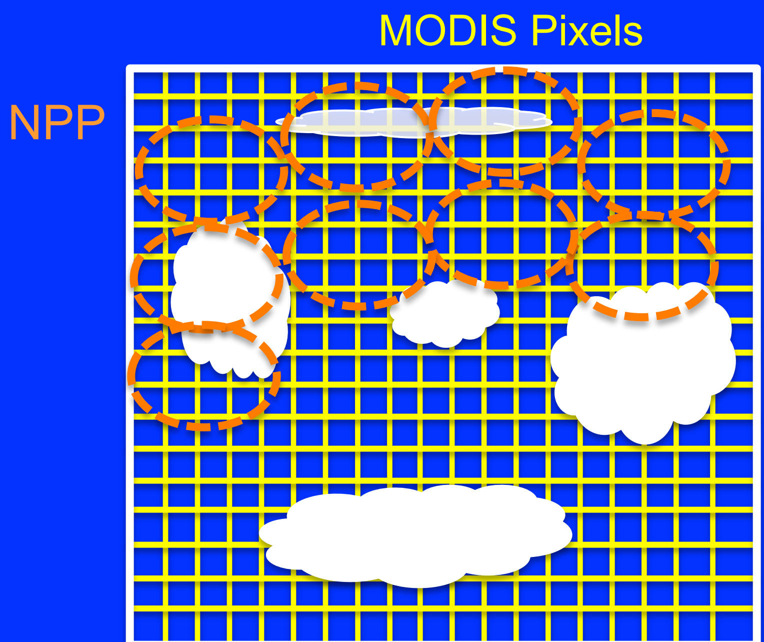
RMS error decreases as ln(fτ) increases: mixed clouds



RMS error decreases as ln(fτ) increases: ice clouds







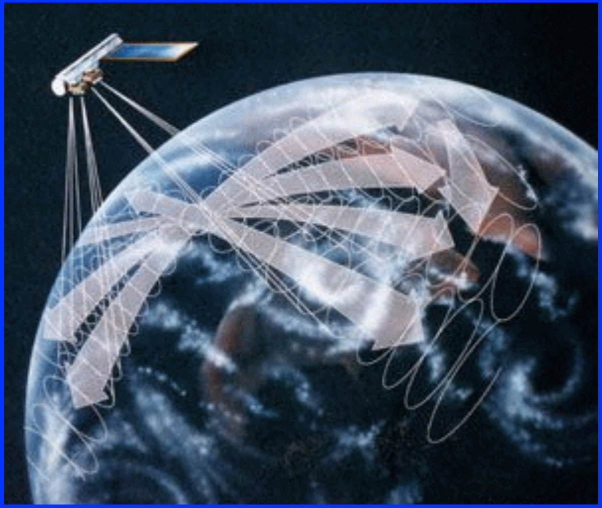
Simulate Aqua and NPP footprints to quantify flux error due to different footprint sizes

- Derive broadband radiances for these simulated Aqua and NPP footprints

$$I_{sw}^{md} = d_0 + d_1 I_{0.65} + d_2 I_{0.86} + d_3 I_{1.63}$$

- Based upon the scene identifications of the simulated Aqua and NPP footprints to select the ADMs
- Compare gridded fluxes from these simulated Aqua and NPP footprints to quantify the effect of different footprint size on flux

Rotating Azimuth Plane (RAP) scan for RBI



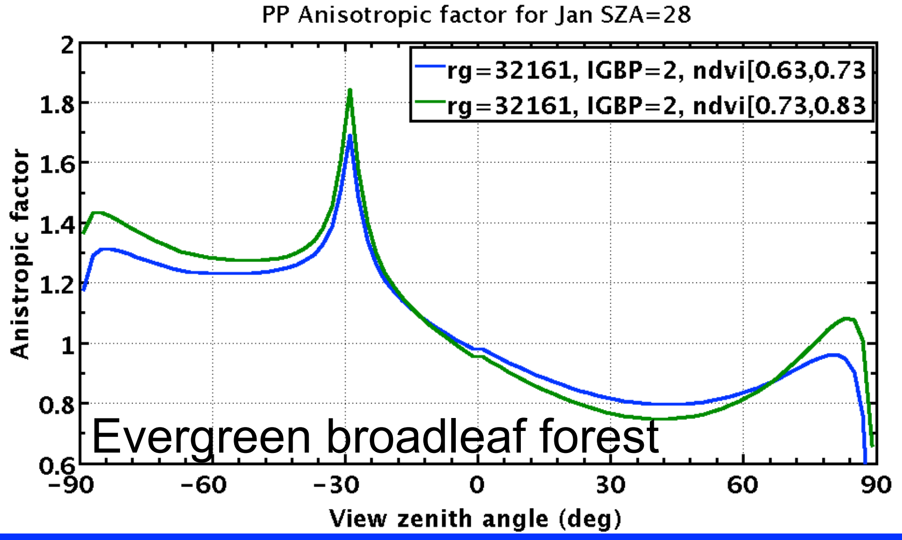
- Build one set of ADMs with 2 years of RAP measurements: referred to as "2yrADMs"
- Build another set of ADMs assuming only taking RAP measurements every third day during the 2-year period: referred to as "reduced 2yrADMs"
- Apply these two sets of ADMs to Aqua data
- Investigate instantaneous flux difference on footprint level and on grid box level
- Only tested clear land and clear ocean

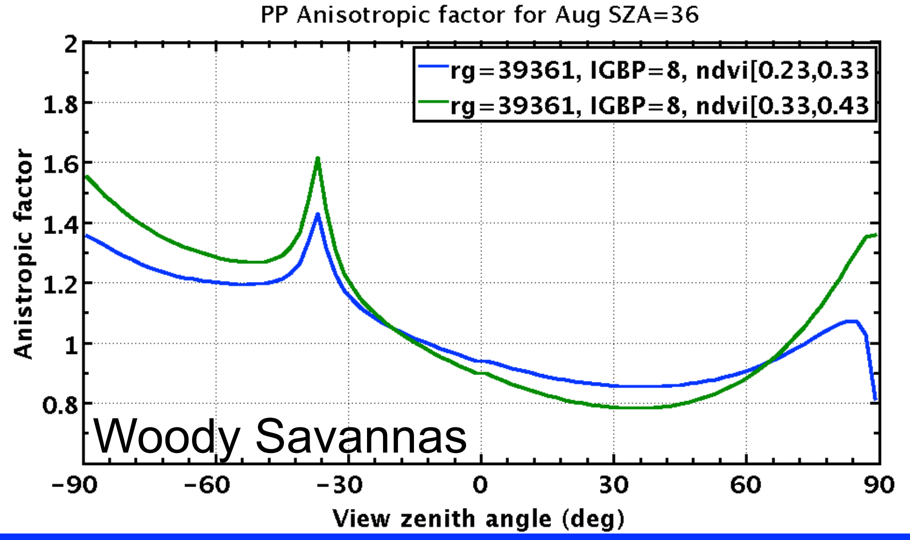
SW angular distribution model over clear land: Modified RossLi

- Collect clear-sky reflectance over 1°X1° regions for every calendar month
- Stratify reflectance within each 1°X1° region by NDVI (0.1) and $\cos\theta_0$ (0.2), and by elevation variability (EV) over rough terrain
- Apply modified RossLi fit to produce BRDF and ADM for each NDVI, $\cos\theta_0$ and, EV intervals within each 1°X1° region

$$\rho(\mu_0, \mu, \phi) = k_0 + k_1 \cdot B_1(\mu_0, \mu, \phi) + k_2 \cdot B_2(\mu_0, \mu, \phi)$$

from Maignan et al., 2004



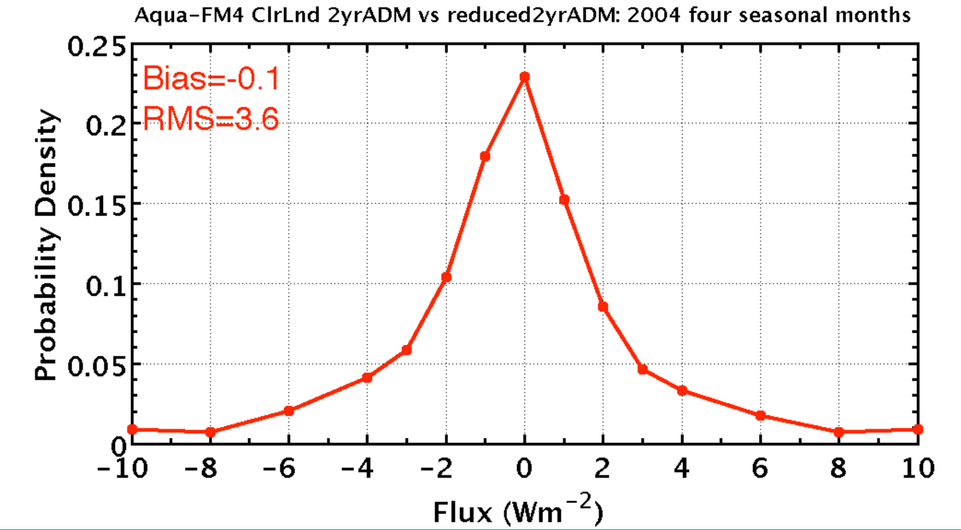


Number of clear land ADMs is reduced by 25-30%

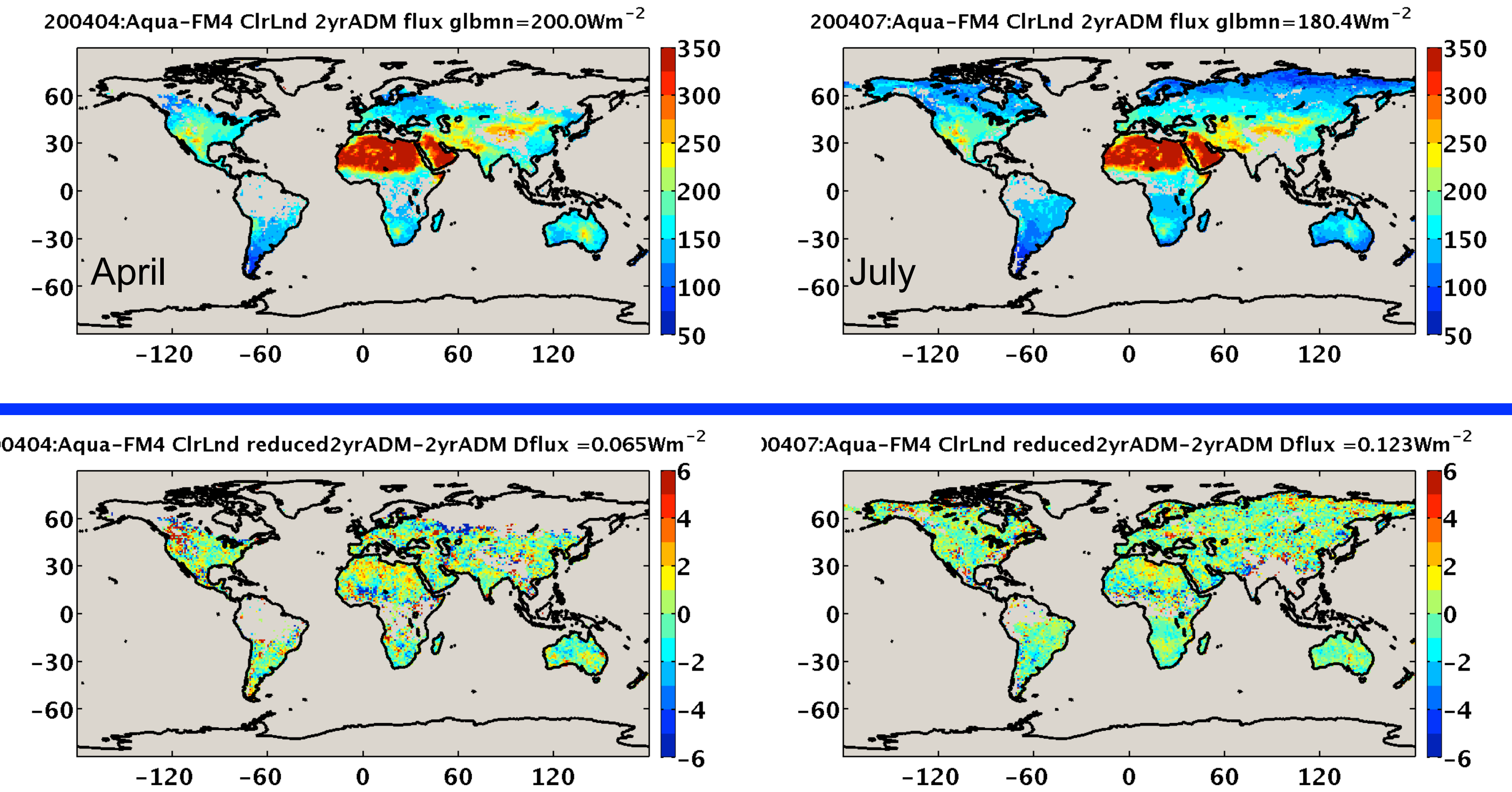
# of clear land ADMs	2yr of RAP	RAP every third day
Jan	28555	21303
Apr	48906	33457
Jul	48440	33337
Oct	44094	30562

Footprints with valid fluxes from both sets of ADMs

	Bias (Wm^{-2})	RMS (Wm^{-2})	% of FOVs |Bias|>5	% of FOVs |Bias|>10
Jan	-0.1	3.3	5.8	1.3
Apr	-0.3	4.4	11.2	2.1
Jul	-0.0	3.4	5.3	1.1
Oct	-0.1	3.1	6.2	1.3



Gridded instantaneous flux differences from reduced RAP sampling

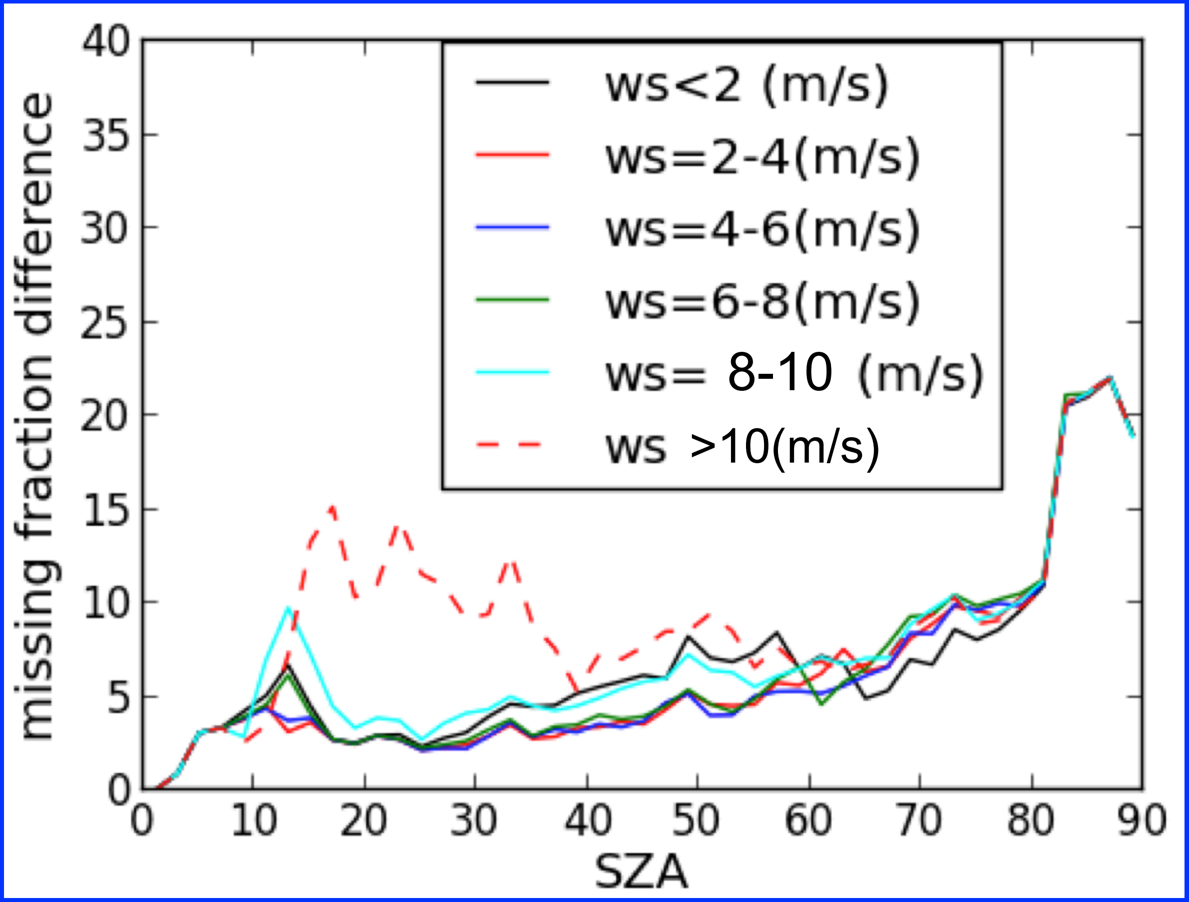


28% of grid boxes with Δflux > 2Wm-2
8% of grid boxes with Δflux > 5Wm-2

19% of grid boxes with Δflux > 2Wm-2
5% of the grid boxes with Δflux > 5Wm-2

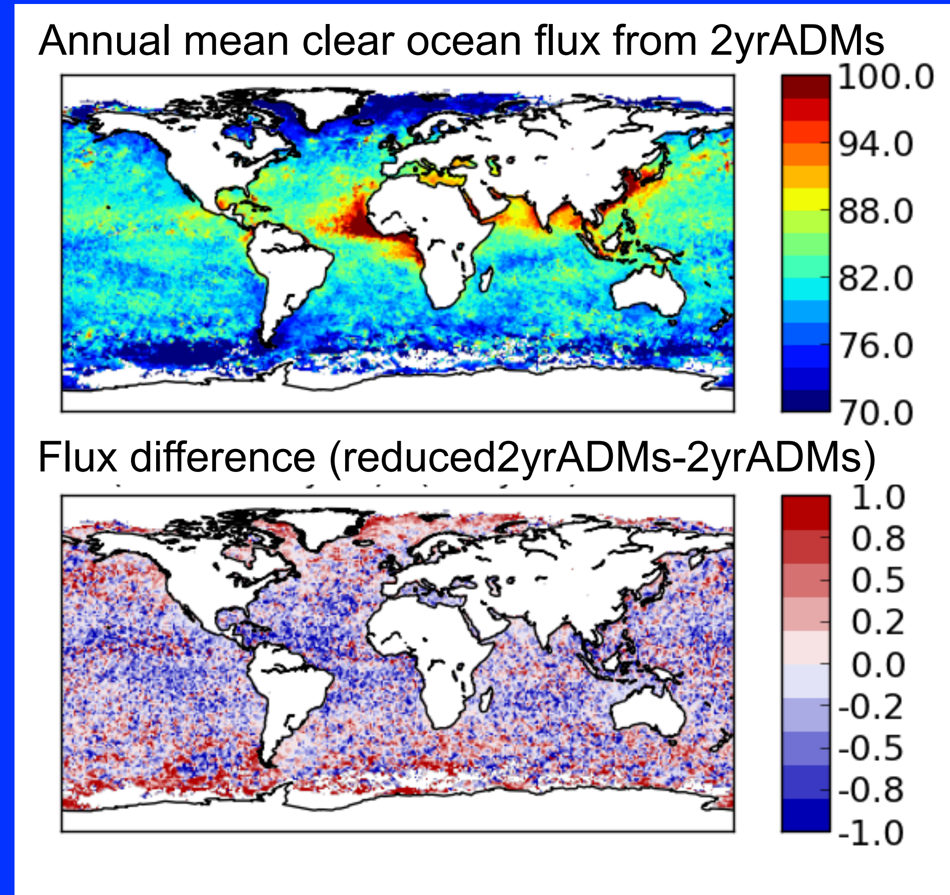
Clear ocean: missing bin fraction increased by 5~10%

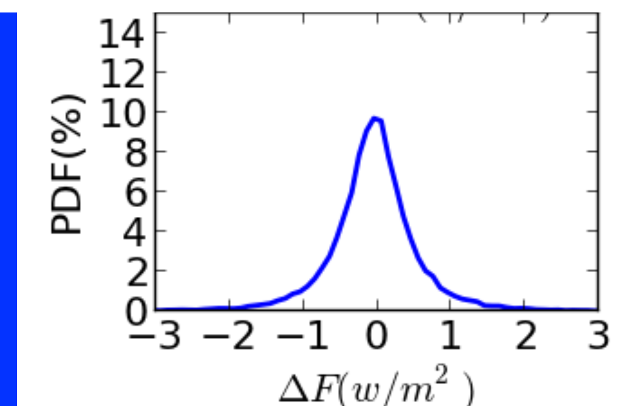
- Clear ocean: R(w, θ_0, θ, ϕ, AOD, aerosol type)
- Build one set of clear ocean ADMs using 2 years of RAP measurements
- Build another set of ADMs using a subset of the these RAP measurements (every third day)



Clear ocean flux difference from these two sets of ADMs

- Apply these two sets of ADMs to one year of cross track data
- The "reduced 2yrADMs" fail to produce fluxes for 2% of the footprints
- The bias and RMS error calculated using matched footprints are 0.0 and 1.2 Wm^{-2}, about 7.3% of the matched footprints with flux difference greater than 2 Wm^{-2}
- Global annual mean gridded instantaneous flux difference is about 0.1 Wm^{-2}, about 10% of the grid boxes have flux difference greater than 1 Wm^{-2} and about 2% of the grid boxes have flux difference greater than 2Wm^{-2}





Future plan

- Assess the effects of different footprint sizes and inconsistent cloud properties on NPP flux inverted using Aqua ADMs
  - MISR multi-angle measurements
  - Compare gridded fluxes derived from simulated Aqua and NPP footprints
  - Compare the radiance vs. ln($f\tau$) relationship derived using CERES-Aqua with that derived using CERES-NPP. Any difference in this relationship indicates that footprint size affects the ADMs
  - Time series analysis: study global/regional deseasonalized trend using CERES-Aqua, then replacing data after 2012 with CERES-NPP
- Extend the RBI rotating azimuth plane sampling study to cloudy land/ocean